

# Chapter 6: Statics of Rigid Bodies

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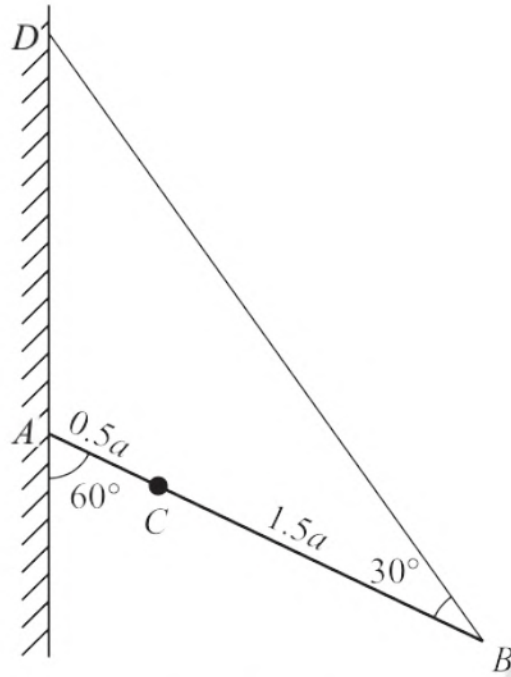


Figure 5

A uniform rod,  $AB$ , of mass  $8m$  and length  $2a$ , has its end  $A$  resting against a rough vertical wall. One end of a light inextensible string is attached to the rod at  $B$  and the other end of the string is attached to the wall at the point  $D$ , which is vertically above  $A$ . The angle between the rod and the string is  $30^\circ$ . A particle of mass  $km$  is fixed to the rod at  $C$ , where  $AC = 0.5a$ . The rod is in equilibrium in a vertical plane perpendicular to the wall, and is at an angle of  $60^\circ$  to the wall, as shown in Figure 5. The tension in the string is  $T$ .

(a) Show that  $T = \frac{\sqrt{3}}{4}(16 + k)mg$  (4)

The coefficient of friction between the wall and the rod is  $\frac{2}{3}\sqrt{3}$ .

Given that the rod is in limiting equilibrium,

(b) find the value of  $k$ . (6)

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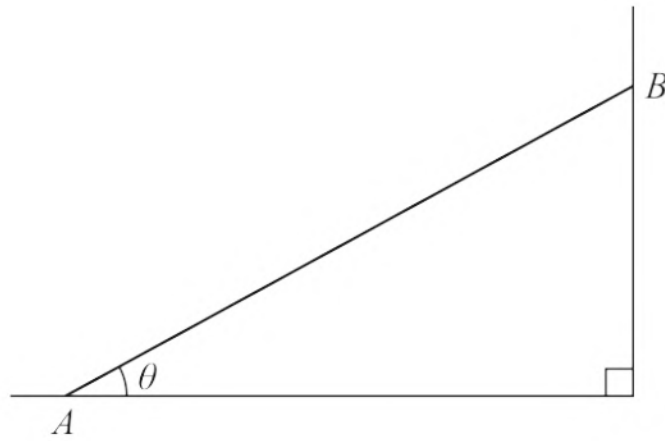


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**Figure 1**

A uniform rod  $AB$ , of mass 25 kg and length 3 m, has end  $A$  resting on rough horizontal ground. The end  $B$  rests against a rough vertical wall.

The rod is in a vertical plane perpendicular to the wall.

The coefficient of friction between the rod and the ground is  $\frac{4}{5}$

The coefficient of friction between the rod and the wall is  $\frac{3}{5}$

The rod rests in limiting equilibrium.

The rod is at an angle of  $\theta$  to the ground, as shown in Figure 1.

Find the exact value of  $\tan \theta$ .

(9)

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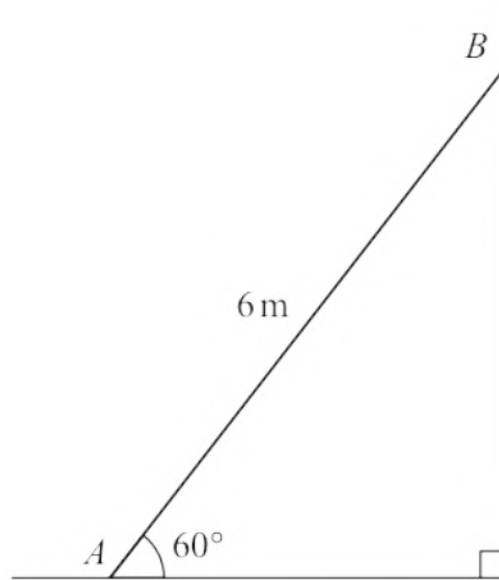
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**Figure 3**

A ladder  $AB$  has length 6 m and mass 30 kg. The ladder rests in equilibrium at  $60^\circ$  to the horizontal with the end  $A$  on rough horizontal ground and the end  $B$  against a smooth vertical wall, as shown in Figure 3.

A man of mass 70 kg stands on the ladder at the point  $C$ , where  $AC = 2$  m, and the ladder remains in equilibrium. The ladder is modelled as a uniform rod in a vertical plane perpendicular to the wall. The man is modelled as a particle.

- (a) Find the magnitude of the force exerted on the ladder by the ground. (6)

The man climbs further up the ladder. When he is at the point  $D$  on the ladder, the ladder is about to slip.

Given that the coefficient of friction between the ladder and the ground is 0.4

- (b) find the distance  $AD$ . (4)

- (c) State how you have used the modelling assumption that the ladder is a rod. (1)

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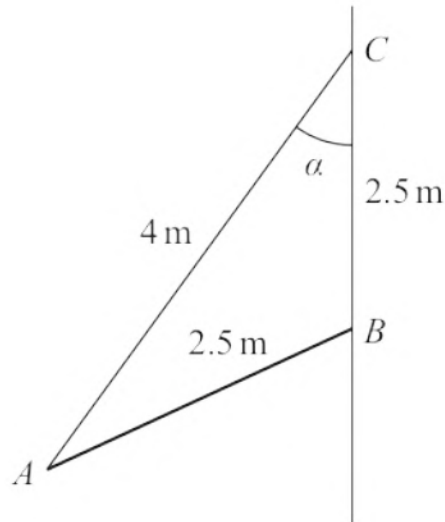


Figure 2

A pole  $AB$  has length 2.5 m and weight 70 N.

The pole rests with end  $B$  against a rough vertical wall. One end of a cable of length 4 m is attached to the pole at  $A$ . The other end of the cable is attached to the wall at the point  $C$ . The point  $C$  is vertically above  $B$  and  $BC = 2.5$  m.

The angle between the cable and the wall is  $\alpha$ , as shown in Figure 2.

The pole is in a vertical plane perpendicular to the wall.

The cable is modelled as a light inextensible string and the pole is modelled as a uniform rod.

Given that  $\tan \alpha = \frac{3}{4}$

(a) show that the tension in the cable is 56 N.

(4)

Given also that the pole is in limiting equilibrium,

(b) find the coefficient of friction between the pole and the wall.

(6)

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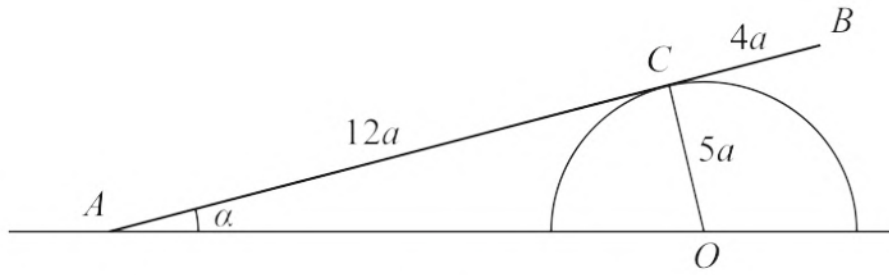
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**Figure 1**

A smooth solid hemisphere is fixed with its flat surface in contact with rough horizontal ground. The hemisphere has centre  $O$  and radius  $5a$ .

A uniform rod  $AB$ , of length  $16a$  and weight  $W$ , rests in equilibrium on the hemisphere with end  $A$  on the ground. The rod rests on the hemisphere at the point  $C$ , where  $AC = 12a$  and angle  $CAO = \alpha$ , as shown in Figure 1.

Points  $A$ ,  $C$ ,  $B$  and  $O$  all lie in the same vertical plane.

- (a) Explain why  $AO = 13a$  (1)

The normal reaction on the rod at  $C$  has magnitude  $kW$

- (b) Show that  $k = \frac{8}{13}$  (3)

The resultant force acting on the rod at  $A$  has magnitude  $R$  and acts upwards at  $\theta^\circ$  to the horizontal.

- (c) Find (8)
- (i) an expression for  $R$  in terms of  $W$
  - (ii) the value of  $\theta$

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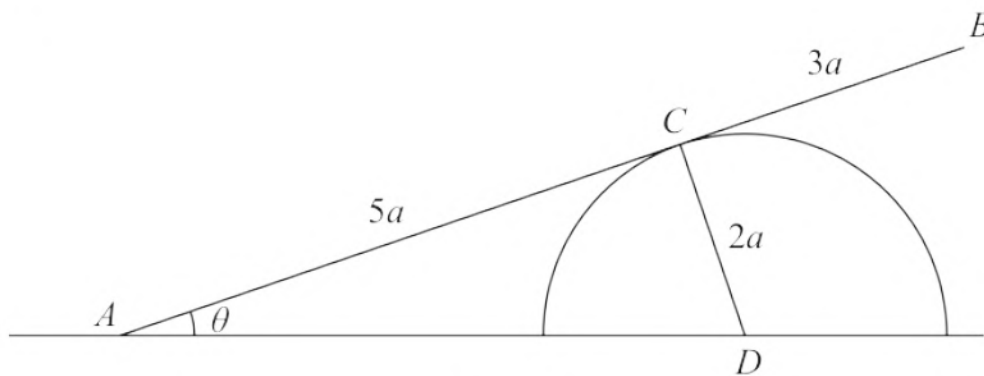


Figure 1

A uniform rod  $AB$  has length  $8a$  and weight  $W$ .  
 The end  $A$  of the rod is freely hinged to horizontal ground.  
 The rod rests in equilibrium against a block which is also fixed to the ground.  
 The block is modelled as a smooth solid hemisphere with radius  $2a$  and centre  $D$ .  
 The point of contact between the rod and the block is  $C$ , where  $AC = 5a$   
 The rod is at an angle  $\theta$  to the ground, as shown in Figure 1.  
 Points  $A$ ,  $B$ ,  $C$  and  $D$  all lie in the same vertical plane.

(a) Show that  $AD = \sqrt{29}a$  (1)

(b) Show that the magnitude of the normal reaction at  $C$  between the rod and the block is  $\frac{4}{\sqrt{29}}W$  (3)

The resultant force acting on the rod at  $A$  has magnitude  $kW$  and acts at an angle  $\alpha$  to the ground.

(c) Find (i) the exact value of  $k$   
 (ii) the exact value of  $\tan \alpha$  (8)

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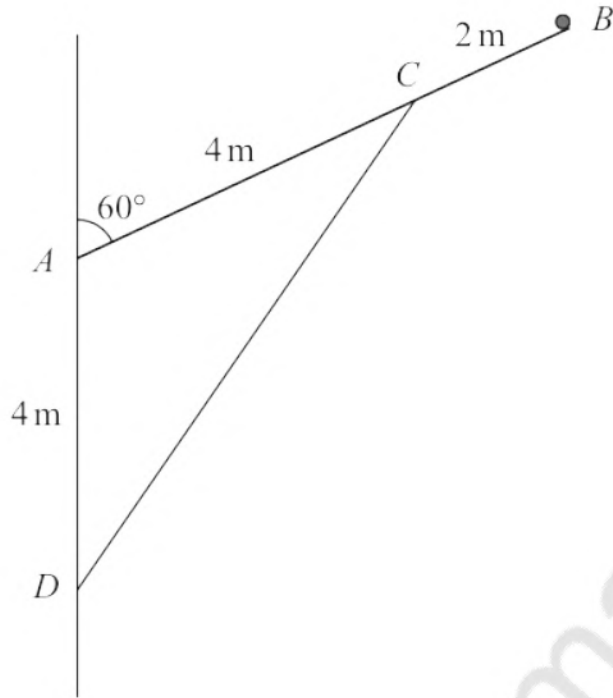
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**Figure 3**

A uniform pole  $AB$ , of weight  $50\text{ N}$  and length  $6\text{ m}$ , has a particle of weight  $W$  newtons attached at its end  $B$ . The pole has its end  $A$  freely hinged to a vertical wall.

A light rod holds the particle and pole in equilibrium with the pole at  $60^\circ$  to the wall.

One end of the light rod is attached to the pole at  $C$ , where  $AC = 4\text{ m}$ .

The other end of the light rod is attached to the wall at the point  $D$ .

The point  $D$  is vertically below  $A$  with  $AD = 4\text{ m}$ , as shown in Figure 3.

The pole and the light rod lie in a vertical plane which is perpendicular to the wall.

The pole is modelled as a rod.

Given that the thrust in the light rod is  $60\sqrt{3}\text{ N}$ ,

(a) show that  $W = 15$

(4)

(b) find the magnitude of the resultant force acting on the pole at  $A$ .

(6)

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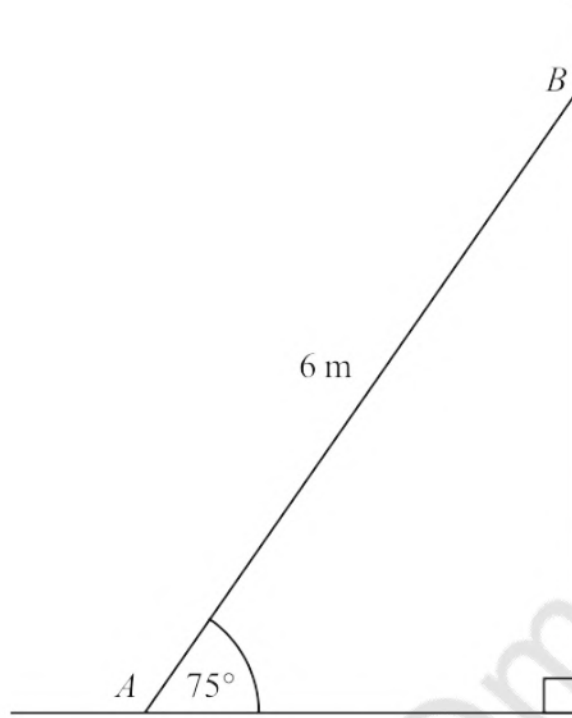
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**Figure 2**

A uniform beam  $AB$ , of mass 15 kg and length 6 m, rests with end  $A$  on rough horizontal ground. The end  $B$  of the beam rests against a rough vertical wall.

The beam is inclined at  $75^\circ$  to the ground, as shown in Figure 2.

The coefficient of friction between the beam and the wall is 0.2

The coefficient of friction between the beam and the ground is  $\mu$

The beam is modelled as a uniform rod which lies in a vertical plane perpendicular to the wall.

The beam rests in limiting equilibrium.

(a) Find the magnitude of the normal reaction between the beam and the wall at  $B$ . (5)

(b) Find the value of  $\mu$  (6)

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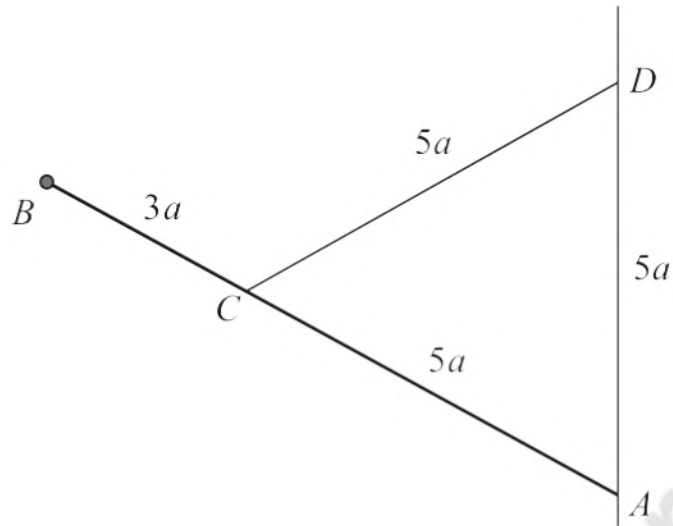


Figure 4

A uniform rod  $AB$  has length  $8a$  and weight  $W$ .

The end  $A$  of the rod is freely hinged to a fixed point on a vertical wall.

A particle of weight  $\frac{1}{4}W$  is attached to the rod at  $B$ .

A light inelastic string of length  $5a$  has one end attached to the rod at the point  $C$ , where  $AC = 5a$ .

The other end of the string is attached to the wall at the point  $D$ , where  $D$  is above  $A$  and  $AD = 5a$ , as shown in Figure 4.

The rod rests in equilibrium.

The tension in the string is  $T$ .

(a) Show that  $T = \frac{6}{5}W$  (3)

(b) Find, in terms of  $W$ , the magnitude of the force exerted on the rod by the hinge at  $A$ . (6)

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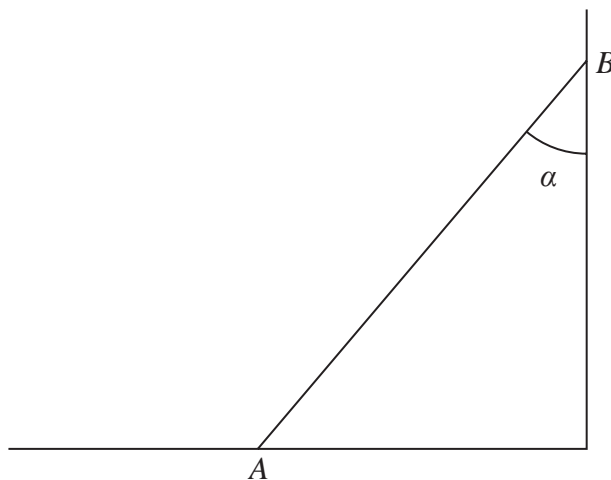
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**Figure 2**

A uniform rod,  $AB$ , of mass  $m$  and length  $2a$ , rests in limiting equilibrium with its end  $A$  on rough horizontal ground and its end  $B$  against a smooth vertical wall. The vertical plane containing the rod is at right angles to the wall. The rod is inclined to the wall at an angle  $\alpha$ , as shown in Figure 2.

The coefficient of friction between the rod and the ground is  $\frac{1}{3}$

(a) Show that  $\tan \alpha = \frac{2}{3}$  (6)

With the rod in the same position, a horizontal force of magnitude  $kmg$  is applied to the rod at  $A$ , towards the wall. The line of action of this force is at right angles to the wall.

The rod remains in equilibrium.

(b) Find the largest possible value of  $k$ . (4)

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